1. Introduction

1.1 Background

Coir is the fibre from the coconut fruit. It is a common experience that fibres detached from the coconut skin are quite hard to break by simple tension, hence by pulling from both sides. Excellent properties of resistance to wear and easy availability in countries, such as Sri Lanka, where coconut palms are widespread, have allowed coir to be employed for a variety of uses, e.g., for manufacturing toys, bags and carpets. More recently, coir has also found additional applications, which appear to be gradually replacing the traditional ones and possibly create an alternative market for coir and coconut palms by-products (Moir 2002). For example, coir is recently used to manufacture containment nets aimed at protecting soil from erosion, thereby replacing polyester nets, with the added advantage that coir nets will not need to be removed eventually, since they act as an active support to plants growth (Rao *et al.,* 2000)**.** Another interesting possibility is the replacement of wooden boards with coconut husk boards, obtained using a compression moulding process with no added chemicals. Coconut husk is a residue from coconut production, comprising approximately 30 wt.% coir fibres and 70 wt.% coir pith. These boards proved to have sufficient moisture resistance to be employed in upholstery (Van Dam *et al.,* 2004).

The latter example is particularly suggestive of a field of application, which is becoming increasingly important in the last decade, and which can present both environmental and economic importance, in particular for the developing countries: the use of vegetal fibres to obtain materials capable of replacing plastics. This replacement is likely to be largely supported worldwide in the near future, in that it presents substantial environmental advantages, including the fact that a wider use of plant fibres in materials offers a better end-of-life scenario for the components (Czigany 2004). In the particular case of the automotive industry, restrictions on scrapped car disposal are gradually coming into force, such as the directive adopted by the European Commission in September 2000 (directive 2000/53/EC), which impose a larger use of bio-degradable materials in car manufacture (European Commission 2000).

These examples seem good news for the countries producing plants suitable for fibres extraction: however, the automotive market is dominated by a few gigantic companies, with capitals owned in developed countries, and this may introduce again a “cash crop” philosophy in dealing with plant fibres as plastic replacement materials (Moir 2002). In addition, a number of different fibres are available and already investigated, or in some cases used for material reinforcement: a list has been compiled, which is reported in Appendix. This can possibly result in a competition between producer countries, most of which are located in the Third World, so that the fibres would be paid as low-cost commodities, and consequently their market would have a scarce effect on development.

In the complex situation of plant fibres market for plastic replacement, the case of coir in Sri Lanka has been selected for study, for three main reasons. Firstly, coir is a by-product of coconut palms: these offer a number of products, including some primary ones (e.g., palm oil, coconut flesh) (a detailed list is given in Table 1.1). Therefore, coir fibres production would not mean, at least in principle, to introduce a new "cash crop". Secondly, in Sri Lanka a long tradition exists of using coir to produce a number of different items, among which are puppets, bags, mats, etc. Therefore, this country appears to be in a good position to use this local fibre in plastics replacement materials. However, for coir technology to have really a positive impact on development in Sri Lanka, the whole cycle of production of coir-reinforced materials (from fibre extraction to finite product) has ideally to be carried out in the country (Jafferjee 2002). Thirdly, in comparison with other developing countries, Sri Lanka has a relative political stability, which should allow, at least in principle, a continuous and steady supply of fibres to materials manufacturing (Mason 2003).

Table 1.1 Coconut products

Product	**Description**	**Major markets**
Desiccated coconut	Desiccated coconut, made out of coconut kernel, is used in the confectionery industry.	European Union, Finland, Turkey, Egypt, United Arab Emirates and Brazil.
Coir twine	Made out of bristle fibre (long fibre) or bristle fibre mixed with omatt fibre (short fibre) according to buyer specifications.	USA, UK, France, South Korea and Japan.
Doormats (Handmade/Machine made)	Doormats are made out of coir twine or yarn or coir fibre mixed with jute yarn.	European Union and Bulgaria.
Doormats (Coir with steel springs)	Doormats are made out of coir fibre using steel springs, especially suitable for winter.	Germany, Netherlands and UK.
Charcoal Briquettes	This product, made out of coconut shell, is especially processed for outdoor and indoor barbeques as well as for domestic heating.	Middle East

Activated Carbon	The raw material used for the manufacture of activated carbon is coconut shell charcoal. Coconut shell charcoal, unlike wood and coal, is not chemically activated and is therefore ideally suited for use in food processing and the production of medicines. These can be used in various industries for purification.	USA, South Africa, UK, Japan and Canada.
Geotextiles	Geo-textiles, used for erosion control, soil stabilization and landscaping, are environmentally friendly materials.	South Korea, Japan, Netherlands and Germany.
Rubberised Coir Products for Horticultural and Agricultural Industry	Inner layers of flower pots, basket liners, support poles for creepers and rubberised coir geotextiles are manufactured by spraying coir fibre with compounded latex.	Korea, Japan, Netherlands and Germany.
Rubberised Coir Mattresses	Mixture of coir fibre and latex is steam heated, pressed and vulcanised to produce mattresses.	Germany and Japan.
Coco Peat Products	In the process of extracting fibre from the coconut husk, the residue, which consists mainly of a powdery mixture, is known as coco peat and is used as a substitute for peat moss in Europe. Coir peat is exported in briquettes, blocks, disks or grow bags and forms.	Netherlands, Italy, Japan, South Korea and Taiwan.
Coconut Cream and Milk	100% pure concentrate of coconut kernel, without artificial flavours or preservatives, is used in curries and desserts.	UK, Middle East, Netherlands, Australia, France and Germany.

The above considerations suggest that the possibility exists for a renovated coir industry to be determinant for the development of Sri Lanka economy, bringing an environmental advantage to the whole world. This is a present issue, because in the next few years a substantial part of the process of replacement of plastics with biodegradable materials is likely to take place: therefore, this work is also trying to investigate how the situation will evolve in the foreseeable future.

1.2 The research problem

Dealing with new uses for coir, a different perspective in the use of coir fibres also exists, which is particularly evident in the automotive industry. This concerns the use of plant fibres to replace glass fibres in composite materials i.e., materials including fibres as a reinforcement of a plastic resin, widely used in cars manufacturing (e.g., interior and door panels, bumpers). Recent legislation is aimed at making vehicle dismantling and recycling more environmentally friendly, setting clear quantified targets for reuse, recycling and recovery of vehicles and their components and *pushing producers to manufacture new vehicles also with a view to their recyclability*. As an example, the 2000/53/EC Directive prescribes that from January 1, 2015, 95% of the mass of these cars is to be recycled and only the remaining 5% can be burnt to produce energy.

In this respect, the biodegradability of plant fibres will become of even greater importance in the next decade, also because of the gradual introduction of *fully sustainable composites*. These are obtained embedding plant fibres in a biodegradable (e.g., cellulose-based) matrix replacing oil-derived polymer matrix, and are likely to have a considerable positive impact on environment (Rowell 2002). It is noteworthy that, whatever the application, a requisite to have an environmentally friendly material is the limitation, or ideally the absence, of non-biodegradable chemicals throughout the process leading from the fibre extraction to the fabrication of component. In practice, the most common reasons for treatment of fibres with chemicals are fungal growth prevention (Tsuchiya *et al.,* 2003), improvement of rigidity (Rout *et al.,* 2001) and odour masking (Witek *et al.,* 2004). At this subject, recent criticisms concerned the scarce use or dissemination of LCA (Life Cycle Analysis) results in components made partially or exclusively using natural materials, such as coir fibres (Clift 2004). An extensive use of LCA would allow evaluating the environmental friendliness of the process leading to fibre extraction and the criticality of the quantities of chemicals introduced (if any).

However, the environmental advantage needs to be added up with the envisaged social advantage i.e., the extent at which coir fibres production and marketing are able to contribute to the development of the main producing regions: Sri Lanka and some states of India, such as Kerala (Rammohan 2003). In practice, for environmental gain to be apparent also in these regions, it is not sufficient to reverse the current trend of growing plastics use in developing countries, coming back locally to the traditional multi-purpose use of coir fibres. In contrast, a limit needs also to be put to coconut palm plantations, trying to avoid monoculture and rather improving the exploitation of the existing palm trees (Jafferjee 2002). Difficulties in this process are likely to be encountered not only as an effect of the centralised structure of the automotive industry, as discussed above, but also a consequence of the local government structure, which may not be able to cope with pressure from multinational companies. The specific objection is that South-Asia people and institutions should work their own way through the current economic systems, challenging unequal distribution to resources. Failing this, poor people will continue to carry the burden for the all round environmental degradation and will be enmeshed in problems, processes and policies, such as cash-crop exploitation of fibre producing crops, and slip much deeper into poverty (Gopalakrishnan *et al.,* 2004). In addition, further exploitation of plant fibres with insufficient safety measures, as may be the case in a “cash crop” context, may worsen some typical problems of developing countries, such as Sri Lanka, as the presence of parasite-borne diseases. For example filariasis, a disease due to lymphatic parasites from anopheline mosquitoes (Nair 1961), was linked with coir cropping, especially because of water pollution due to retting (i.e., fibre extraction and cleaning) in South India and Sri Lanka (see Nelliyat 2003).

1.3 Justification

Plant fibres production issue is crucial for both environment and Third World development. Coir, which has been used for at least 4000 years in Sri Lanka, may have the potential to become an environmentally friendly material of large use in the world. Natural rubber, recently coupled to coir in a number of industrial products (e.g., rubberised coir, which consists of natural latex and coir hair moulded into cushions and pads for the automotive industry) is also cropped in Sri Lanka, and this adds to the possibility of developing a local industry on coir-based plastic replacement products (Chand 1995).

In the long run two extreme scenarios for plant fibres use can be imagined: either they will foster the development of Third World economy with added advantage for environment at planetary level, or they will be a further natural resource exploited in a "cash crop" philosophy from multinational companies, with negative impact locally and globally.

In the case of coir production in Sri Lanka, two possibilities for the balance to be more favourable to the former scenario than the latter have been singled out: diversification of agricultural products (i.e., harvesting different plants that have conditions of cropping compatible with coir) and diversification of coconut palm products (including palm oil, coconut fruits and coir pith). In Sri Lanka, concern has been expressed about the exploitation of coir in a “cash crop” philosophy, so that experiments of diversification of agricultural production are taking place already, albeit with unimpressive results in terms of yielding and economic impact on the country (Moir 2002). However, the success in environmental terms of this operation will depend on how this change from oil-based plastics to natural plastics will be conducted at the different levels of political, economic and industrial decision-making.

Also, investigating what is happening or is likely to happen in Sri Lanka in the next few years for the coir market and the coir-products industry, can stimulate discussion about other Third World countries and plant fibre market. The reason for this is that Sri Lanka appears to be in a particularly favourable position to develop an industry, which will have a positive impact on environment worldwide and on development locally. To achieve this, strategies have to be implemented by the international community in the Sri Lankan case, which could also be applied in the more distant future in other developing countries.

The aim of this research was to investigate the issues of coir production and marketing in Sri Lanka, and the potential of this fibre to reduce the worldwide environmental impact of plastics and contribute to the development of the country.

Within its overall aim, the research was meant to contribute to:

- Develop a detailed understanding of the present reasons for an increased use of plant fibres. This has been achieved making the specific case of coir, discussing impact of plant fibre production on environment and development, especially in the case of Sri Lanka.
- Discuss the present and future role of the different actors, including local government, international organisations, and agricultural and industrial partners. This enabled understanding the possible stakeholders’ contribution to the successful development of coir-based production in Sri Lanka for an environmental-friendly material.
- Suggest improvements in fibre processing or marketing, presenting added environmental benefits. This would be aimed at contributing to move the balance towards an increased environmental friendliness of coir processing.
- Develop a conceptual model, trying to incorporate economic and environmental benefits of coir fibre with environmental and social problems, linked to coir exploitation.

1.4 Methodology

This research was structured using a deductive approach from the theory, developed e.g., in Gopalakrishnan *et al.* (2004), that the possibility exists that environmental protection measures, involving Third World countries, can result in further deprivation for poor people, rather than in development. A number of actors, including e.g., governments, international organisations, and industries, are involved in possibly addressing this process towards real development, as well as improved conditions for the environment. In particular, the research was focused on the use of plant fibres as a replacement for fibreglass, which appears to present environmental advantages, as reported in section 1.2. Most plants used for fibres are cropped in Third World countries, hence the interest of investigating the possible presence of a “cash crop” philosophy in this production.

This research has been developed as a longitudinal case study, concentrating on the possibilities and difficulties of the use of coir for production of fibres in Sri Lanka, and their social and environmental result. The approach was that of a review of literature, collecting also, as far as possible, primary information from stakeholders in the process.

1.5 Delimitation of scope

This research deals with the environmental impact of materials and goods produced using plant fibres, concentrating then on the specific case of coir in Sri Lanka. In this respect, it is aimed at evaluating the possible environmental gain obtained worldwide with a larger use of plant fibres, trying to clarify which are the economic aspects involved and whether the final balance is likely to result in some development of the producer countries or rather in further exploitation of resources, often defined as "cash crop" philosophy. The actors and the forces involved in the process of replacing non degradable with biodegradable materials have also been discussed, for as concerns the selected case study. The discussion over methods for sustainable forest management in the specific case of coconut plantations has not been included in this research, being much wider than the issues dealt with in this work. It is intended that, once it is demonstrated that a significant environmental and social benefit can originate from the development of coir production in Sri Lanka, coir production needs to be integrated in coconut plantations managed in an environmentally sustainable way.

1.6 Outline of the dissertation

In Chapter 2, a survey of the economic and technical literature dealing with the use of plant fibres in materials has been presented, with particular reference to publications related with use of coir in Sri Lanka and that explain the economic and environmental perspectives of this market. In Chapter 3 the different sources of information have been described, particularly concentrating on the use of LCA literature, a market survey on biodegradable materials and a conceptual model of coir market. The results obtained are presented according with the different elements of the model in Chapter 4, and conclusions about the possibility that coir market, and more in general plant fibres use, can have a positive effect on development rather than resulting in further Third World exploitation are traced in Chapter 5.

1.7 Summary

In this chapter, the background of the problem has been introduced, in particular considering the interest of replacing oil-based plastics with natural fibres, extracted from plants. The specific case of coir industry has been exposed, as a possible trigger for development in Sri Lanka, the largest world producer of this fibre. Concerns expressed in literature about the possible use of plant fibres, and coir in particular, as “cash crops” for the exclusive benefit of the developed world, have also been voiced. The structure of this work, including an environmental and economic study of coir, included in a conceptual model, has finally been presented.

2. Research definition

2.1 Introduction

In recent years, new applications for coir have increasingly become available. These include in particular their use as geo-textiles and as reinforcement for plastics, and are part of a general trend of employing plant fibres in more environmentally friendly materials and components, especially in building and automotive industry. The main producers of coir are Sri Lanka and some states of India, such as Kerala.

This chapter is aimed at clarifying whether these new uses of coir can benefit the social and economic situation in Sri Lanka or in contrast will propose some aspects of "cash crop" exploitation. In addition, the global effect on environment of plastic replacement with plant fibres will be investigated.

More in detail, the practical problem section (section 2.2) is focused on the possibility of using coir and on the particular position of Sri Lanka in this respect. The theoretical problem (section 2.3) concentrates on suggestions offered in literature on the possible application of plant fibres in materials manufacturing and its effect on the environment, on the whole importance of coconut production, and on its possible consequences on Sri Lanka social life and development. The research problem section (section 2.4) presents gaps in knowledge on three possible main questions, then exposed in section 2.5: possible "cash cropping" of coir, actors and factors in the globalisation process in the specific case of Sri Lanka, and global effect on the environment of plant fibres use in materials.

2.2 The practical problem

The plant fibres market has been declining for the last two decades, due to the decreasing appeal in the developed world for their traditional applications (e.g., hemp mountaineering ropes were replaced with polyester ones) (Stark 1995). In the case of coir, other issues are deemed to have contributed to make this negative trend more significant. According to Nair (2002), among these were the scarce worldwide knowledge of the range of possible applications for coir and coconut palm products, and the insufficient collaboration between producer countries to improve quality control and marketing.

In recent years, this negative trend seems to be gradually counterbalanced by effect of a renovated interest for plant fibres as oil-replacement materials. For both environmental and economic reasons, the international community is trying to develop this new market, with the idea that it might become a possible route for Third World development.

However, a number of difficulties can be perceived in this process. Firstly, the technological process to extract fibres and produce materials needs to be completely chemicals-free, whilst presently, to improve fibre adhesion to the plastic matrix, heavy treatments (e.g., bleaching with alkali), are still in use (Anto 1997). Secondly, the transportation costs need to be reduced in absolute value or at least reduced in percent of the marketed product: this can be achieved by manufacturing the materials as close as possible to the cropping field and by involving large volume production industries (Bruce 1996). Thirdly, the bulk of the plant (not just the fibres) needs to be used for a number of different purposes, so to minimise the quantity of waste produced and increase the value of the crop (Bisanda *et al.,* 2003). In addition, a large volume production requires a reasonably constant supply of fibres. This implies that cultivation needs to be planned for a period of three to five years, which is not always possible in countries often unstable both socially and politically (Moir 2002).

The above difficulties can be possibly addressed, if the government has a clear statement for action in this field. This is what is happening for example in the UK with flax fibres. Here, DEFRA is trying to "find alternative, profitable uses for land released from surplus production" with the aim to economically sustain the production of flax until the new uses, connected with the development of renewable industrial materials, become predominant and economically viable (NNFCC 2004). It is noteworthy that this process needs to include a selection of the plant varieties most suitable for exploitation and an improvement of the extraction process and final quality for plant fibres e.g., via the use of appropriate enzymes (Eichhorn *et al.*, 2000). Specific research projects are ongoing, also in the UK, which are aimed at improving plant fibres quality. An example is the Texflax consortium, managed by De Montfort University and including companies operating in different sectors (textiles manufacturing, weaving machines, sustainable agriculture) and with an interest in flax (Texflax 2003).

In the particular case of Sri Lanka, this country is gradually passing from traditional manufacturing of coir to the production of plastics-replacement materials using this fibre, also owing to processes for mechanical fibre extraction, which recently became widely available. The situation of Sri Lanka is particularly interesting in this context, because it is a traditional producer of both coir fibres and natural rubber, which are often coupled in new “environmentally-friendly” plastics, for example for use in mattresses and pillows. In the whole of the coir-producing countries, a reaction appears to be taking place against the decline of coir industry, in particular trying to revive the traditional expertise on coir yarn preparation for manufacture of different items (e.g., bags, carpets). In particular, the Coir Board is organising training programmes in coir yarn spinning and weaving of coir geotextiles for women, with the aim of providing self-employment opportunities to the rural women artisans in regions producing coir fibre. The idea is that conversion of coir fibre into yarn using motorised ratt, involving the use of multiple spinners in rural households, could provide large-scale employment, better working conditions and higher income in these countries (Coir India 2004). In spite of these attempts, it appears evident that a major impact on Sri Lankan economy would probably need the involvement of large "added-value" industries, such as building companies and especially the automotive sector. However, the need to obtain automotive components with a number of properties, including e.g., biodegradability, absence of odour, structural resistance and easy finishing, has brought automotive manufacturers to be rather attracted by products obtained combining two or more natural fibres (often referred to as *hybrids*) (Snijder *et al.,* 2000). In this respect, Sri Lanka has not a position as good as a much larger country as India in the wealth of possible natural fibres that can be used, beyond coir. For example, in India jute/coir boards are being produced as wood-replacement materials and mixed jute/coir nets for geotextiles and plants growth media for nurseries. This allows having a material obtained on 100% local technology, with very good mechanical and moisture absorbing properties, due to the synergy between the two fibres, one with higher cellulose content (jute) and another with lower cellulose content (coir) (Coir India 2004). On the other side, Sri Lanka is in a better position than many surrounding countries for possible coir exploitation, because it is more politically stable, with an ethnic problem reasonably under control, and it is not over-populated, although still a developing country (Mason 2000). A success of the "plant fibre policy" in Sri Lanka would lead to more attempts being done in other developing countries, as conversely a failure may affect the confidence in plant fibre materials as a boosting factor for development in the whole Third World.

2.3 The theoretical problem

A large number of research papers exist on the possibility of using plant fibres as a replacement for glass fibres: a very exhaustive review is in Eichhorn *et al.* (2002). Specifically on coir reinforced composites a few papers are particularly suggestive of current trends and issues: Aggarwahl *et al.* (1991) on the possible use of coir for wood replacement panels, Banerjee *et al.* (2002) on coir fibre properties, Rout *et al.* (2001) on their possible improvement and Srilathakutty *et al.* (2000) on the use of coir as filler in plastics. In addition, a project by FAO-IGHF, funded by the Common Fund for Commodities and carried out at Delft University of Technology and Industrial Technology Institute, Colombo, Sri Lanka, allowed the selection of technologies appropriate for the production of these materials and the manufacturing of demonstrator components with coir fibre reinforced plastics, such as furniture boards (CFC 2003). This gives some ideas of the possible use of coir fibres for less technological uses, also of some importance for the environment, e.g., as a replacement for plywood, medium density fibre (MDF) boards and inorganically filled polymer materials (Bledzki *et al.,* 1999).

An added advantage is offered by the possibility of embedding plant fibres in the so-called bio-based polymers (or simply bio-polymers). These can be synthesized in nature by living organisms or plants (e.g., silk or lignin), or artificially produced by chemical modification of cellulose or starch (e.g., polylactate) (Chiellini *et al.,* 2004). Biopolymers have a high level of biodegradability, which makes them, once coupled with plant fibres, the basis for a fully sustainable material. As discussed in Chapter 1, this is of particular interest in some industries, such as the automotive sector, where a high content of recyclable and/or biodegradable material will be required for cars produced after 2015 (European Commission 2000).

On the problems of coir industry, an interesting report has been provided by Brian Moir of FAO (Moir 2002), concentrating on the difficulties for this industry to come out with new products, such as plastic replacement boards. The all-round potential of coir in sustainable composite materials are nevertheless expressed by Mohanty *et al.* (2002), whilst Khedari *et al.* (2003) and De Kreji *et al.* (2001) focus on two possible end-of-life scenarios for coir fibres, in the form of pith (desiccant for air conditioning systems) or dust (agent for plant growth).

However, coir fibres are only one of the many products coconut palms are able to offer. In particular, coconut palms are grown in tropical countries mainly for the high oil content of the endosperm (copra), which is widely used in both food and non-food industries (e.g. margarine and soaps). Large production areas, in particular, are found along the coastal regions in the wet tropical areas of Asia in the Philippines, Indonesia, India, Sri Lanka and Malaysia. In these countries, millions of people make a living from the coconut palm and its many products. In order to understand the potential of the coconut plant, other applications, not strictly linked with coir (coconut fibres), need to be mentioned. Two examples can be *coconut shell charcoal*, as a general-purpose industrial purifier, not chemically activated (Reed *et al.*, 2004), and therefore ideally suited for use in food processing and the manufacture of medicines, and *coconut flesh* in confectionery. These two examples suggest on one side the presence of considerable profits linked to coir, but on the other side emphasise the fact that current strategies to make the most out of coconut products have always involved a large occurrence of export, which was traditionally encouraged by governmental organisations. A more complete list of products from coconut palm has been reported in Table 1.1, which shows the wide range of application of this plant. The real question is which is the possibility to create a market for coir and other coconut products, able to contribute at improving the economic and social situation of local people in producing countries, resulting in a worldwide benefit for environment. Nair (2002) suggests as key factor the collaboration between coir producing countries, in presence of an internal political stability. Sri Lanka appears to be in a good position from the latter point of view, because recent studies pointed out as the particular inter-ethnic communication patterns helped to orient ethnical differences towards ethnical separatism rather than ethnical revolution, resulting in an improved stability of the country government (Mason 2003). Moreover, recently started liberalisation programme was successful up to a point, ending more recently in an economy "slowly running out of steam", so that new products and/or new markets for local products might be necessary for an improved development (Dunham *et al.,* 1998). It is also important to clarify the relationship between economic and sustainable development goals, as suggested in comments to the recent Johannesburg Summit on Sustainable Development (UNCED 2002). A confused approach mixing the two goals can result in a pretext to introduce "market liberalisation, public-private partnerships and foreign direct investment as main drivers and funding mechanisms" (Von Frantius, 2004). In the specific case of coir yarn spinning, it has been found important that the commodity chain i.e., the network of labour and materials aimed at supplying the commodity e.g., the coir yarn, is embedded into the social tissue of the environment in which production takes place (Rammohan *et al.*, 2003). The two approaches are in a sense complementary and may be able to create a barrier against "cash cropping" of coir. In particular, it is essential to detail which can be the local issues capable of hinder the development of a modern, environmentally and socially sustainable coir industry in Sri Lanka. These are exposed in the following paragraph.

In the case of plant fibres, the transportation costs and the low cost of the fibre may suggest limited local manufacturing, hindering the market opportunities for the fibre products. In practice, the whole process of transformation of fibres into the final material, encompassing fibre extraction and treatment, materials manufacturing and production of components, should be carried out in small plants as close as possible to the fields. Otherwise, to allow transportation at larger distances, high compression in bags or bales in usually practised. However, this method is unlikely to address the need for controlled moisture content. In addition, in some developing countries, such as Brazil, the transportation market is concentrated in few hands i.e., is a kind of oligopoly, and therefore the prices for transportation can fluctuate significantly, or else the transportation of bulky and low value items, such as fibres, may be refused. This needs political stability and a government capable of imposing right prices for transportation, if not international agreements (Andrade 2004). It is important to clarify if the latter conditions apply to Sri Lanka.

Moreover, in the absence of local expertise on biochemical processes of fibre retting, improvement of fibre properties passes always through fibre treatment using chemicals, disposing of which may create further environmental problems. In more environmentally aware countries, such as Sweden, an enzymatic approach aimed at the reconstruction of the material from cellulose microfibrils contained in the plant fibres has been proposed (Lundgren 2004). In this way, the use of different fibres to have different properties in the component could be avoided, as the use of chemicals, and the biodegradability would not be affected in any way

(Mathew *et al.,* 2002). This would possibly allow a major breakthrough into the automotive industry, for example through Indian-Sri Lankan collaboration: however, it has been proved that stringent environmental legislation, as is the case e.g., in Europe, has a beneficial effect in the implementation of production strategies including biodegradable materials (Spengler 2003).

2.4 The research problem

The multiplicity of uses for coir fibres, presented above, would possibly suggest that there could be no problem in exploiting locally this fibre. In reality, most applications need a significant technological expertise, which is presently only available in developed countries, especially on the aspects of fibre chemical and/or enzymatic treatment, crucial to improve fibre properties. In addition, it may become convenient for the coir producer, in presence of a strong request for the fibre from multinational companies, to sell it untreated, instead of developing a local industry with higher technological content, also for the bottle-neck represented by enzymatic fibre retting and the specialised biochemical knowledge required for it. The way out of this issue seems to be to enhance and improve the industry of coir and allied product manufacturing in Sri Lanka, in order to adequate the production to quality standards (Steele 1997). What starts to be apparent is also the multiplicity of chemical-free products that can be obtained using coir fibres, including upholstery, agricultural products (growth media) and geotextiles, even without considering the use of coir for plastic reinforcement. The latter needs the involvement of high-value industries, such the automotive sector: it will be important at this stage to verify which collaborations or international agreements involving Sri Lanka are possible in this field and the effect of these on the environment and social tissue in the country.
A number of actors are present, which can contribute to the transformation of this industry: these may include national and regional government, international organisations e.g., Food and Agriculture Organisation (FAO) or World Trade Organisation (WTO), multinational companies and end-users (e.g., automotive manufacturers). In addition, the role of local people has not to be dismissed: oil-derived plastics are often presented in the Third World as a more "modern" and "wealthy" material than traditional ones. Therefore, the degree of environmental awareness of Sri Lanka people and their ability to resist this "pressure" can be important in the long run (Moir 2002). In this regard, there appears to be an alternative point of view about Sri Lankan economy, as exposed e.g., in “Dust and dolls”, a video produced by the Asian Woman Association (Dust and Dolls 1999), which examines the environmental issues in an eco-feminist perspective. The video describes as Sri Lanka used to have a protected economy, with people leading simple lives with rich traditions and cultures, until in 1977 the new Sri Lankan government sought to achieve higher economic growth by looking up to the "four dragon" economies i.e., Hong Kong, Singapore, South Korea and Taiwan. The contrast between the two

positions, the one striving for "modernity" and the second one, more concerned with traditional manufactures, needs to be further investigated, to see if both positions can find a compromise aimed at the safeguard of environmental and social situation in Sri Lanka.

All the above considerations did not address, nonetheless, a basic question about the use of plant fibres e.g., coir, in materials i.e., the real environmental friendliness of this process. In general, Life Cycle Analysis (LCA) of composites has become of wide interest in the last few years, as it is demonstrated e.g., by the organisation of a first workshop on this subject at the University of Plymouth, to be held in April 2005. Some LCA-based studies exist on China reed fibre used as a substitute for glass fibre as reinforcement in plastics (Corbière-Nicollier *et al.,* 2001) and more generally on plant fibre composites (Joshi *et al.,* 2004). Energy saving obtained with plant fibres is overall recognised, resulting in considerable carbon storage potential (Pervaiz *et al.,* 2003). However, a difficulty in applying the results of these studies to the specific case of coir in Sri Lanka can be perceived, in the fact that technologies used for materials manufacture are strictly mimicked on those used with fibreglass. This means that either the technology may be not available/not applicable locally, or the environmental benefit can be even higher if technologies specific for the local fibre are employed. In addition, Life Cycle Analysis may not take into account local economic aspects, which are crucial to the success of the initiative (e.g., in the case of coir, fibre transportation costs): other instruments may be more suitable for a sounder analysis of the real global (environmental, social and economic) gain, such as the Econo-Environmental Return (EER) (Bage *et al.*, 2003).

2.5 Research questions

Three types of possible problems can be envisaged:

- Is the production cycle of coir-reinforced materials as environmentally friendly as the fibre intrinsically is? Plant fibres extraction may need the use of chemicals: there is technology and environmental scope to avoid this use e.g., via enzymatic treatment, but there is still concern about the final properties and suitability for use of the chemical-free material. This question broadens the investigation from the fibre to the production process, trying to set up considerations for the study of Life Cycle Analysis in plant fibre composites.
- Are aspects of our past capitalist exploitation of the Third World, such as "cash cropping", involved in the present coir market? Answering this question will mean to understand where the profits are going to be generated, and which part of them will result in development of the countries. This is a general question, involving more market study and the possible action of international organisations (FAO, WTO)
- Can the idea that every country should use local fibres for production of materials be

applied in a global economic context? Globalisation affects the whole world economy, so it probably naïve to think that large scale production can be "transplanted" into the cropping field without problems. However, the question is justified, because basic technological knowledge is present in the Third World, as in Sri Lanka, in the form of traditional manufacture of goods using plant fibres, which can be possibly used if new materials are going to be produced from them.

2.6 Summary

Coir was put in this chapter in its context, as a by-product of coconut palm, therefore a part of a much larger market. In addition, the not negligible complications for fibre extraction and for their development in materials were presented, which may suggest a contrast between the traditional way of working on coir in Sri Lanka and the hi-tech procedure adopted in new materials e.g., for automotive applications. These aspects require not only environmental considerations, in the form of Life Cycle Analysis, to examine the validity of this "new" use of coir. An economic analysis would suggest also the involvement of a larger community, including also international organisations, able to evaluate and possibly correct the relation between local fibre manufacturers and concurrence in the global market.

3. Methodology

3.1 Introduction

This research concerns the evaluation of social and economic benefit of the application of coir, and more generally of environmental gain obtained in using coir as a replacement for plastics in geotextiles and automotive applications, in the specific case of Sri Lanka. The methodology selected was that of a longitudinal case study, focused on the period 2005-2015, to see what could be the likely evolution of coir market in Sri Lanka and see which are the factors able to contribute to the development of the country together with an environmental gain.

The selected approach is justified in section 3.2, whilst in section 3.3 the sources of information are detailed, and the conceptual model developed to take into account all the stakeholders and the factors involved in this issue is presented.

3.2 Justification of the methodology

This investigation started from the observation that a raw material which is mainly produced in the Third World, such as coir, but can be of interest for large companies either multi-national or based in the developed world, for example for the production of components to be used in the automotive industry, is likely to generate a "cash crop" process. This is well known, and results in production and trade having a scarce positive impact on Third World development: in contrast, the crop may be damaging for the environment, the economy and the social tissue of the developing country, which is likely to become even more dependant on the effect of the prices set by the multinational companies (Rammohan 2003).

The above considerations made it difficult to design the research with an inductive approach, in particular because there is a cause-effect relationship set already in literature i.e., that high value production from Third World raw materials would possibly imply using plants for fibres as cash crops, as is the case e.g., for cotton. To decide not to consider this hypothesis, which has been the starting point for this research, would only be possible by regarding coir fibres as low value products used locally in low cost application, such as traditional ones (mats, rugs, toys, etc.). This would also exclude any reflection on the possibility that plant fibre products may actively contribute to Third World development, because there appears to be no reason for an economic spin-off originating from coir, if no new coir application is found, as suggested by Moir (2002).

As a consequence, a deductive approach was selected. In addition, the study of plant fibres as "cash crops", even if focused on just coir, is deeply linked to the political and social situation of the specific fibre-producing country, in this case Sri Lanka, so that a *case study* research was selected. A survey would have equally appeared suitable to test the research hypothesis: however, this would have required the boundary of the phenomenon to be clearly defined, so that a sample of units could be successfully extracted from a defined population. This appears not to be the case: a "cash crop" philosophy does usually not only affect the farmers' class, but the whole lower-income sector of the population, and can have hardly predictable consequences, not necessarily confined in a single nation. For example, Turner *et al.* (2000) observed that "structural adjustment programs may even emphasize export or other cash crops", and "foreign military and food aid intervention […] could well be part of a larger pattern of repressing autonomous sustenance agriculture"**.** This last aspect has also implications far back in history, as the result of colonial policies; therefore, it will become crucial to restore the significance of international collaboration in this field, as a trigger for a sustainable development (O' Laughlin, 2002). Consequently, it is difficult to tell how far back the boundaries of a cash crop philosophy can be extended. In contrast, in the case of plant fibres a timescale has been set, at least in the European Union, because the replacement of fibreglass with biodegradable materials in the automotive industry needs to be completed as far as possible by 2015, therefore it appears sensible to work on a specific case in a rigid timeframe.

This empirical research was therefore carried out as a longitudinal case study, with the idea of understanding whether and in which measure the production of plastic replacement materials from coir in Sri Lanka would improve environment and promote development in the country in the next few years. The comparison and contrast of different points of view was crucial for the success of the project. In particular, primary and secondary information was collected from coir producers, international organisations, material scientists (on sustainable composites and issues related), end users (especially from the automotive industry) and, as far as possible, from local people in Sri Lanka involved in any way in coir cultivation and especially manufacture of coir-based products. Collected data was used with two specific objectives: to produce indications on which forces/factors are favouring or hindering the use of coir fibres in Sri Lanka, and to understand which can be the underlying reasons for the present situation, and which can be the impulses for change.

This approach was deemed to be justified when considering, as Moir (2002) reports, the wide range of properties and primary uses of plant fibres and the worldwide complexity of their market. As a consequence, the environmental and economic balance of plant fibres production, use and marketing would depend on the botanic species, which are cropped for extracting fibres in every single country. In addition, the final environmental gain of using plant fibres in place of plastics or glass fibres in a number of products depends heavily from the political situation of the country. Therefore, the idea was to start from one fibre (coir) in one developing country (Sri Lanka) for one main use (production of composites) to see which is the effect on the

economic situation in the country and on the global environmental situation. Sri Lanka was an ideal object of study, since it is both the second largest coir producer in the world after India and one of the few developing countries that it is actively concerned with the possibilities of developing plant fibre market to improve national economy and environment (Kiriella 2002).
This study allowed establishing the dominating factors and the stakeholders in this process, and possibly giving indications that can be of general purpose. From an environmental point of view, as shown in the literature review, there appears to be scope for the replacement of plastics with biodegradable materials. However, this process becomes really sustainable only if it does not involve any form of exploitation of people and resources in developing countries, which is what this research was aimed at clarifying.

3.3 Research procedures

Collection of information

Information from coir fibre producers and users (building industry e.g., for erosion nets) and end-users of coir fibres reinforced composites were needed. In particular, Indian (Maruti), German (BMW, Daimler-Benz) and Italo-Brazilian (FIAT Brazil) automotive industry make an increasing use of plant fibres for panels and even structural components (bumpers). Problems with confidentiality suggested discarding the possibility to acquire primary information from industries, and try in contrast to find information on this subject from other sources. This appeared to present the added advantage that information provided from independent sources (e.g., international organisations, research reports) are likely to be more objective on the possible uses of plant fibres in high added-value applications and in particular on coir. In particular, two sources of first-hand information were obtained. The first one was at the meeting of the Hard Fibres Board of FAO in Rome on 26th March 2004, where indications on the global fibres market and on the projects supported from FAO concerning plant fibres. This was achieved through personal communications (interviews) from a number of members of the committee present there, as reported in the References (Andrade 2004, Peralta 2004).
The Common Fund for Commodities of FAO also partly finances Fast Track projects in the field of agriculture, including projects on natural fibres. As defined by CCP (2001), Fast Track Projects involve limited funding, up to US$ 30,000 per fast track project, though this funding can sometimes be combined with that of other donors, such as the Technical Centre for Agricultural and Rural Cooperation EU/ACP, to multiply the effect of CFC contributions. FAO contributes experts, documentation, organizational management and sometimes meeting facilities and simultaneous interpretation to these fast track workshops. It is noteworthy that two recent Fast Track projects concerned specifically the use of coir: one on use of coir in

composite materials (CFC 2003) and the second on a comparative study of coir with other natural materials for use in geo-textiles (CFC 2004).

The second source of primary information was the conference on Plant Fibres and Wood in Kassel, Germany, on 27-28 April 2004. Here, not only a number of papers on automotive components obtained using plant fibres were presented, but also the presence of representative from a number of companies involved in plant fibres exploitation allowed clarifying the possibilities and limits of substitution of glass fibres with plant fibres. An interesting aspect was also the resistance imposed by the industry, especially with regard to mechanical requirement, but also for the adoption of traditional habits and technologies (Snijder 2004). Discussion on a number of papers (Specht *et al.,* 2004, Medina *et al*, 2004, Fischer*,* 2004) concerned the importance of guidelines and regulations from National and International boards to promote the production of chemical-free fully biodegradable boards and composite materials. This is suggestive of a trend significant also in automotive industry, where the customers' influence seems not to be sufficient to promote a higher biodegradability of the final product, without any "coercive" intervention (Spengler 2003). Information have been obtained by participating at the discussion on the papers mentioned above, in particular asking in the discussion on the paper by Specht *et al.,* to clarify the importance of guidelines and regulations for the development of use of fully biodegradable materials in the wider world. Other primary information on plant fibre perspective from a materials science point of view were obtained by contacting and interviewing other experts in their workplace (Bonser 2004, Jeronimidis 2004).

Reports of international organisations are obtained by personal subscription to INFOTERRA, a mail list for environmental discussion, sponsored by FAO, which chairs a specific discussion group on Hard Fibres, producing a substantial amount of literature on coir market since the early nineties, including reports on coir-focused conferences (Moir 2002) and production and use of geo-textiles made with coir (CFC 2004). The latter was particularly interesting, in that it highlighted the effect of the competition of different fibres (and of different Third World countries) on the global market of natural geo-textiles.

During literature review, two marketing possibilities appeared to be viable to reduce the cash crop impact of coir in Sri Lanka. These are either to develop the multiplicity of products obtained from coconut crops (see Table 1.1), or to increase the number of products obtained from coir presenting industrial interest. On the second aspect, there is considerably less literature and research (CFC 2003). With this in mind, a market research, carried out from the University of Portsmouth in a combined project with the University of Reading (LUBESTARCH), on possible applications for biodegradable materials, including interviews to different companies, was also used. Being the results confidential, the names of the multi-national companies involved have been removed. In addition, the results were only used in the part that can be applicable to coir. The market survey included a first phase of interviews, and a second phase of "try to matching" the request for new products with the characteristics of possible biodegradable materials. This second phase of the market survey was adapted to the properties of coir, as referred in literature, so to come out with ideas for new products. In particular, a number of questions appear to be crucial in the market survey, namely those concerning *characteristics, volumes and costs of the products in use*, the *interest for a biodegradable alternative*, and the *characteristics required*. On these aspects, the idea was to clarify which of the products required could be obtained using coir, and which can reasonably be obtained locally in Sri Lanka.

Another important question is that of the real impact of plant fibres on the environment, involving LCA (Life Cycle Analysis) studies, such as Pervaiz *et al*. (2003) and Joshi *et al.* (2004). These studies have been adapted as far as possible to coir, trying to set up qualitative considerations on the real environmental advantage. The idea in this case was to understand which are the relevant factors in an LCA study on coir and how these can relate to the economic success of this fibre, both locally and globally. Questions related to the possible "cash cropping" of coir are better dealt with in the model, described in Section 3.3.

Data gathered are analysed trying to model the issues that implanting a production of coir reinforced materials in Sri Lanka will involve and trying to understand if each of them will result in a benefit or not for the environment and development in the country.

Setting a conceptual model

Given the complexity of the problem, a conceptual model has been developed. The rationale for the model is to try to understand if the whole of the coir production does really represent an opportunity for environment with respect to competitive products, for Sri Lanka and for the wider world.

In accordance with the three research questions exposed and with the existing model on competitiveness of coir industry in Orissa in Figure 3.1 (Coir India 2004), the model is divided in three parts. The first part will concern coir industry as an effective possibility for Sri Lanka development, including the possibility of new products being obtained from coir, therefore trying to clarify what is the weight of those referred to as *potential entrants* in Figure 3.1. The second part will focus on the competition between different fibres (and *different developing countries*), which can help or hinder the net profit out of coir industry for each of them (the term *industry competitors* in Figure 3.1 will be investigated). The final part will concentrate on benefits/disadvantages for environment of the production cycle used to manufacture coir fibres and the different options available. This last part will also include some social issues, as for example the case of "professional diseases", such as filariasis, described in Chapter 1. In the model, the term "*substitutes"* is divided into two possible categories: oil-generated products

i.e., plastics, and mineral products, such as glass fibres, because they give rise to different end-of-use scenarios, in that the latter appear more recyclable. Coir can replace either: however, economic considerations also come to place, so the choice may not be completely obvious.
The final aim of this would be to possibly have a net result of the whole operation and suggest how and if the weight of anyone of the issues can be modified in order to improve the final balance.

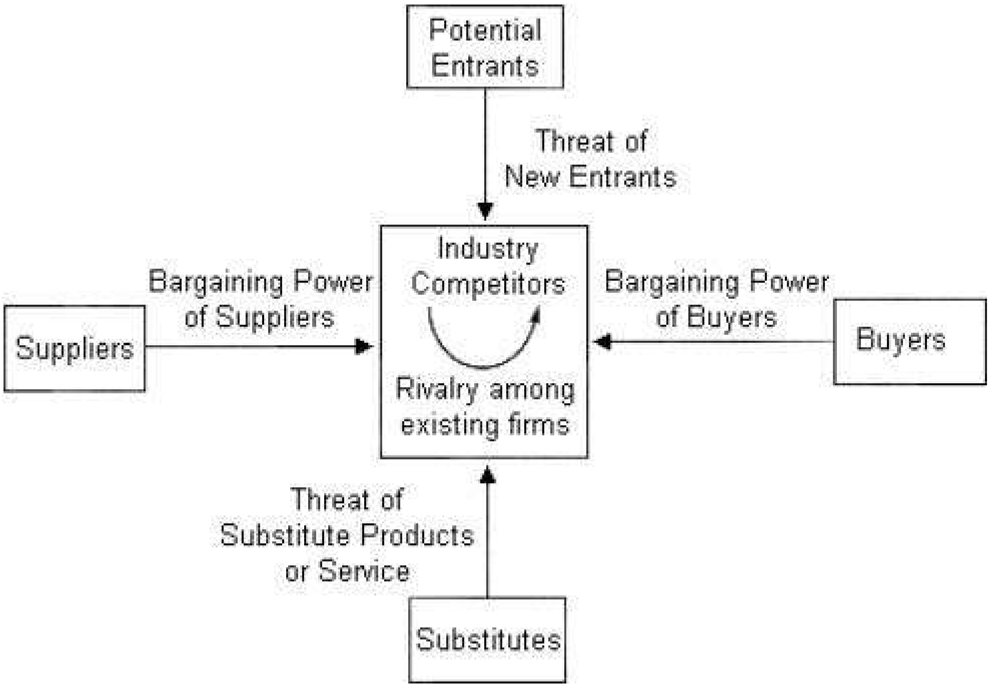

Figure 3.1 Conceptual model for the competitiveness of coir fibre industry (Orissa, India)

Method for model analysis

The model in Figure 3.1, obtained from literature, is modified as follows (represented in Figure 3.2), for the needs of this investigation, according to the discussion in section 3.2.

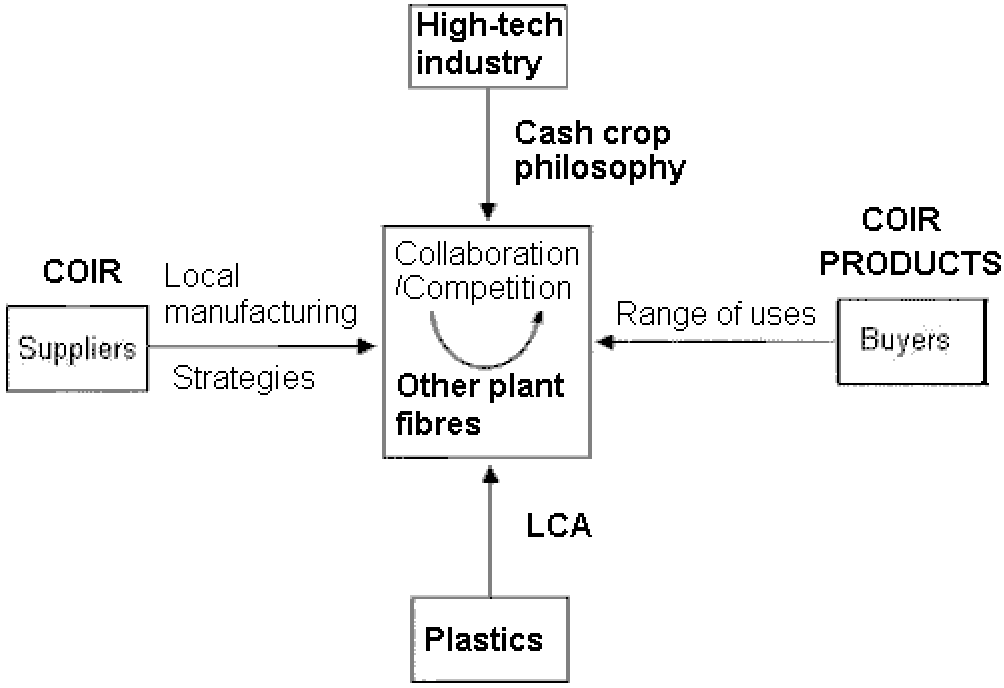

Figure 3.2 Conceptual model for the possible use of coir as plastic replacement

The analysis, exposed in Chapter 4, will initially concern the specific parts of the model, in particular:

- The replacement of plastic-based products with coir products will have to be justified from an environmental point of view: therefore, life cycle analysis (LCA) studies in comparison with oil-derived plastics will need to be considered
- The industrial interest for coir, which can induce possible higher exploitation of developed countries resources, using coir as a cash-crop
- The different needs from the possible buyers of coir products will have to be considered: with this aim, a number of uses for coir will need to be evaluated
- The possibilities for suppliers of coir and coconut palm derivatives to provide material for industrial products to be manufactured, as far as possible, with local workers and expertise

The analysis will then expand to the possible implications of the four components, especially for as regards making coir one of the triggers for a sustainable development of the Third World, in the particular case of Sri Lanka. This would allow linking the model to the research questions presented in section 2.5.

3.4 Summary

The methodology for this work was based on the study of a case with a longitudinal approach, investigating the future perspective of the evolution of coir market in the next few years and its effect on Sri Lanka.

Primary data were mainly obtained at a technical conference on natural fibres, and with the participation at a meeting of the FAO Hard Fibres Group. Secondary data were collected from technical, economic and environmental literature, in particular on Life Cycle Analysis of natural fibres. In addition, a confidential survey about the interest of biodegradable materials in industry was acquired and focused on coir. A conceptual model, found in literature, was adapted to the problem of coir market, with the objective to find a good balance between industrial interest for high-tech biodegradable materials, possibilities offered by coir and alternative fibres and new specific requirements from coir users in the next future.

4. Analysis and results

4.1 Introduction

The evaluation of social, economic and environmental benefits of the application of coir, in the specific case of Sri Lanka, required obtaining and analysing data from coir producers, end-users of coir products and international organisations involved in plant fibres market and Third World development. In addition, data were obtained from scientific literature regarding the aspect of plastic replacement with coir fibres and the two main possibilities for a high-tech use of coir products, namely in geo-textiles and automotive applications.

Primary research is presented in section 4.2, whilst collected data are described and analysed in section 4.3, focusing on the conceptual model introduced in section 3.3. In section 4.4, findings are reported, with reference to the research questions exposed in section 2.5.

4.2 Summary of primary research

The initial plan for this investigation started from two main considerations, which were assumed as realistic. The first assumption was that substitution of oil-derived plastics and glass fibres with natural materials, such as plant fibres, would generate a consistent benefit for the environment. Consequently, the second assumption was that, since many plant fibres, such as coir, are prevalently produced in Third World countries, this could pose the problem of a “cash crop” exploitation of these fibres. This would especially be possible, considering that the prevalent users of glass fibres in polymeric composite materials are companies operating in highly technological industrial sectors, such as automotive and construction engineering.

On the latter aspect, literature seemed to confirm that aspects of a "cash crop" philosophy are present in the development of a modern industry based on natural fibres components. Two strategies seem to be viable to avoid this risk: on one side, Third World countries need to diversify and modernise their industry based on local fibres, whilst on the other side collaboration at an international level can prevent the decline of plant fibres based industry and promote research and development (R&D) in this sector.

As a consequence, primary research needed first to clarify the validity of these two evidences from literature, and then possibly investigate if, in the specific case of *coir in Sri Lanka during the next decade*, a renewed success of plant fibre market is likely to result in environmental and social advantage for this country and more in general for the Third World, within this timeframe.

Contact with industry experts and researchers on plant fibres and composite materials unveiled the fact that the former assumption that plant fibres are more “environmentally friendly” than glass fibres as a reinforcement for polymers could not be taken without some caveats. According to data supplied by Moir (2004), the environmental impact of coconut production is small and the use of pesticides is only incidental. In addition, any use of pesticides and fertilisers can only be partially ascribed to coir fibre production, since coir is the by-product of coconut cultivation.

However, in the traditional production of coir fibre from coconut husks, fibre extraction causes significant negative impact on the environment, because the soaking and retting of the husks for up to 6 months in ponds or lagoons pollutes the surface waters and releases methane, contributing to the greenhouse effect some twenty eight times more than CO_2 emissions. Installation of controlled biological treatment systems for waste water and recycling of process water could reduce the amount of pollution (Moir 2004). More recently, the decortication and extraction process has been conducted by semi-mechanised decorticators, resulting in a reduced period of soaking by several weeks. Nevertheless, the energy required to operate the machines adds to the environmental impact, but no data are available so far. The residual pith, a by-product of decortication, also may constitute waste, if not used as horticultural substrate or peat moss substitute (Van Dam *et al.,* 2004).

Passing to the more specific aspect of the environmental advantage of using plant fibres in place of glass fibres as reinforcement for composite materials, a possible advantage would depend on, depends on the following facts (Joshi *et al.,* 2004):

- Natural fibres production has lower environmental impacts compared to glass fibres production
- Natural fibre composites require higher fibre content for equivalent performance, so that, in the case of oil-derived plastics, less oil and energy consumption is required, and a material with a higher percent of biodegradability is produced
- Light-weight natural fibre composites improve fuel efficiency, reducing emission of pollutants during component service
- End of life incineration of natural fibres results in recovered energy

However, these facts are in industrial practice counter-balanced by other considerations: firstly, processing of plant fibres (chemical treatment) is often needed in order to obtain a sufficient resistance of the material and this is inherently polluting (Corbière Nicollier *et al.,* 2001). Secondly, it is essential to ensure a constant and reliable supply of fibres to the materials industry, and this requires control in transport prices and political stability, capable of allowing crop planning for at least five years (Moir 2002). Difficulties in continuously supplying and transporting fibres at reasonably steady prices were independently perceived by a number of experts (Andrade 2004, Jeronimidis 2004). This clarified that the risk of "cash cropping" on plant fibres for composites can be much subtle than envisaged at the beginning of this study, because of the possible concurrence between fibres and Third World countries, when no serious planning and regulation over cropping, supplying and transportation is set. In practice, a study carried out by independent experts on behalf of FAO singled out clarified that three factors are able to affect the success of plant fibre application in geo-textiles and in composites: product price, reliability of supply and product quality (CFC 2004).

The frequent mention of product quality opened further insight in how, as suggested by the initial assumptions, international co-operation can allow the economic advantage of using coir for Sri Lanka economy to integrate the environmental advantage. In principle, a number of products from coir (and, more generally, from coconut palm plantation) appeared to be of interest for possible end-users (see Table 1.1). Therefore, it was not surprising to find out that the present main objective of international co-operation on coir appears to be improving quality and marketing of fibres and products (SLACMA 2002). Standards applied in Sri Lanka are mainly based on the ones developed from India. In particular, for the coir boards used as wood replacement, standards are already in place for as regards acceptance of components in Bureau of Indian Standards (IS 14842 - 2000), railways, housing and transport corporations (Agarwal 2002). In the same way, the Sri Lanka Coir & Allied Products Manufacturers Association (SLACMA) tried to formulate a Code of Ethics for the coir and allied product manufacturers to improve the quality and country image of the industry with the aim of finally setting up a global marketing approach, including internationally accepted production practices (SLACMA 2002).

All the results presented so far, clarified the need to have a range of high quality products from plant fibres, if these have to become a spin-off for development and to know exactly what the biodegradable materials user would expect from them. This appears far beyond the present reality of coir market. In practice, many of the coir exporting companies are relatively small- or medium-scale enterprises, with scarce ability to keep abreast of changing market needs and to meet the material needs of the larger markets. Most producers provide a wide range of different products, and sell these in relatively small numbers. This contrasts with requirements of the larger conglomerate stores in Europe and elsewhere, demanding relatively large quantities of single items, with firm demands on quality and delivery to schedule. In this way, 'exclusive' products, such as those produced using coir, may be marketed only once. However, if successful, further sales of a different (but similar) product are possible during the following year. In practice, this can create market continuity for the coir fibre producer, albeit for different products (Moir 2002).

A number of social issues were also found to be significant: the Centre for Development Studies (India) looked at coir processing in the state of Kerala, concluding that as unions succeeded in raising wages and improving working conditions, they were also driving factories off to more degraded parts of the country (McKibben, 1995). In Sri Lanka, after 1978, when the country was forced to open its economy as advocated by donor governments and agencies such as the *World Bank* and the *International Monetary Fund* (*IMF*). Sri Lanka became the first country in south Asia to adopt the full package of the *Structural Adjustment Programs* (*SAPs*) of the *IMF* to integrate into the global free market. To attract foreign investment and to make Sri Lankan goods competitive and cheap for export, the Sri Lankan rupee was devalued. To liberalise the market, all subsidies and price control measures on essential food items were stopped. In the specific case of coir production, this meant to stop the tradition of twisting coir ropes in every household, in contrast starting work in large factories in poor health and safety conditions (Daily Mirror 2002).

4.3 Summary of data collected

The conceptual model presented in Figure 3.2 is aimed at describing the current situation and perspectives of coir market in Sri Lanka. This is basically formed by two contrasting set of forces to be weighed and compared, which originate directly from the two initial assumptions in section 4.2: top to bottom, a "sustainability balance" of plant fibres against glass fibres, and left to right, a "marketing balance" of producer expectations and buyers requirements. The core of the model represents the role of the national and international community in promoting development of Sri Lanka through coir market. Each section of the model represents therefore one of the three issues, posed as research questions in section 2.5.

Sustainability balance

Firstly, from an environmental point of view, the model is aimed at comparing coir (left) with oil-based products, generically described as *plastics* (bottom), so to show whether this replacement would improve sustainability. This required some form of “environmental balance” to be carried out, in the form for example of Life Cycle Analysis (LCA) (ISO 1997). In recent years, a number of LCA studies on the employment of natural fibres in composite materials have been carried out. The main interest of these studies is for the automotive industry, which make extensive use of glass fibre reinforced composites (internal panels, bumpers, side intrusion beams, seats) (Brooks 2001). It is not surprising that a number of studies concerned LCA of automotive components realised with natural fibres (Schmidt *et al.,* 1998, Wotzel *et al.,* 1999, Diener *et al.,* 1999, Joshi *et al.,* 2004). It is important, as presented by Joshi *et al.* (2004), to clarify which are the parts of the production cycle where significant advantages are likely to be revealed, replacing glass fibres with natural fibres. These are compared in Figure 4.1 and 4.2, and show that a significant aspect, replacing glass production with fibre cropping, is the need of having fibre extraction and processing close to the cultivation, whilst production of glass and glass fibres can be, and usually is, on the same premises. Transportation may represent then an economic burden, as the production of compatibiliser, in order for the reinforcement fibre to be "accepted" into the plastic can be an environmental one, because it will involve the use of chemicals.

The study by Wotzel *et al.* (1999) was performed on a side panel for a car, in which hemp fibre were used as plastics reinforcement. This resulted in 45% less energy, and lower air emission. Overall, Eco-indicator point scores (Goedkoop 1995) are about 8% less when using hemp instead of glass fibres. Even if hemp is 66% of the volume of the component, it contributes only 5.3% of the cumulative energy demand. In a similar study on insulation components for a car, manufactured using hemp reinforcement, Schmidt *et al.* (1998) measured net benefits for energy and emission of pollutants. These were accounted as 88.9 J in cumulative energy demand, 8.18 kg of carbon dioxide emission, 0.0564 of sulphur dioxide emissions, 0.002 kg of phosphate emissions and 0.018 kg of nitrate emission in the basic scenario, considering a waste disposal in 50% land filling and 50% incineration.

Further extending this concept, recently Pervaiz *et al.* (2003) estimated that 3.07 million tonnes of carbon dioxide emissions (4.3% of total USA industrial emissions) and 1.19 million m crude oil (1.0% of total Canadian oil consumption) can be saved by substituting 50% fibre glass plastics with natural fibre composites in North American automotive applications.

A limit of these studies is that they do not include the aspect of fibre transportation, assuming, quite generously, the cultivation to be at nought distance from the fibre production and treatment plant. In the sake of taking into account a more realistic value of transportation cost, a more suitable tool to evaluate the impact of natural fibres composites may be the Econo-Environmental Return (EER). This is an index created by the combination of the environmental impact assessment results (such as an LCA) and those from an economic assessment. From a simple decision rule, a decision-maker can compare several goods on both environmental and economic aspects (Bage *et al.,* 2003). The application of the EER to natural fibre composites is likely to indicate that if the costs, including transportation ones, are too high to allow for a replacement of glass fibres, then a number of actions could be taken. This would include controlling the transportation costs, or reducing the distance travelled, or else possibly applying other forms of incentive to compensate for the higher cost (Andrade 2004).

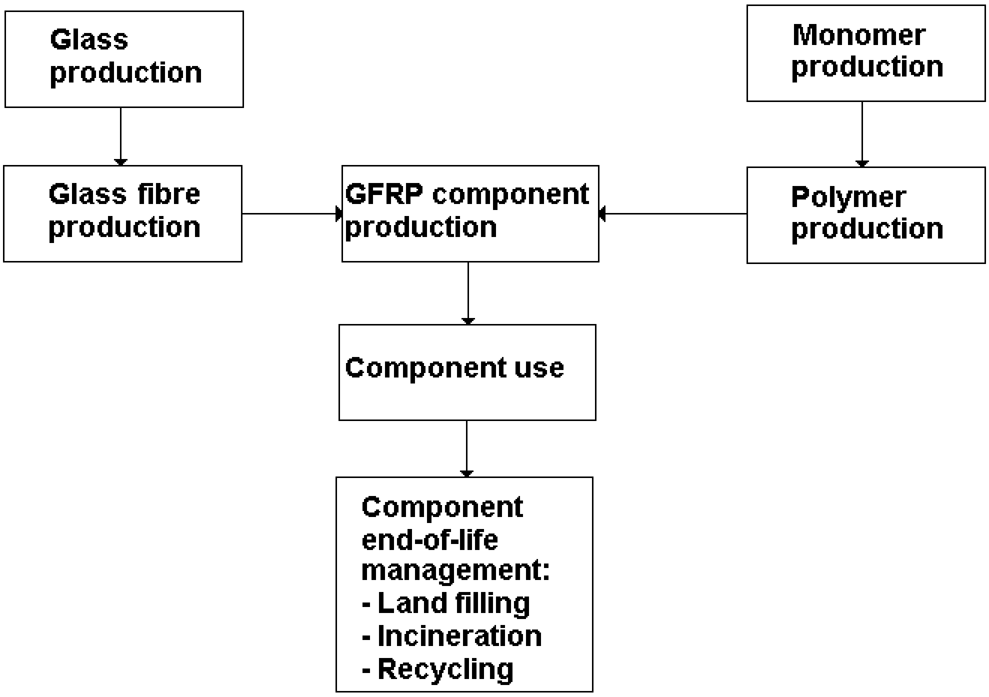

Figure 4.1 Life cycle of a glass fibre reinforced plastic (GFRP) component (elaborated from Joshi et al., 2004)

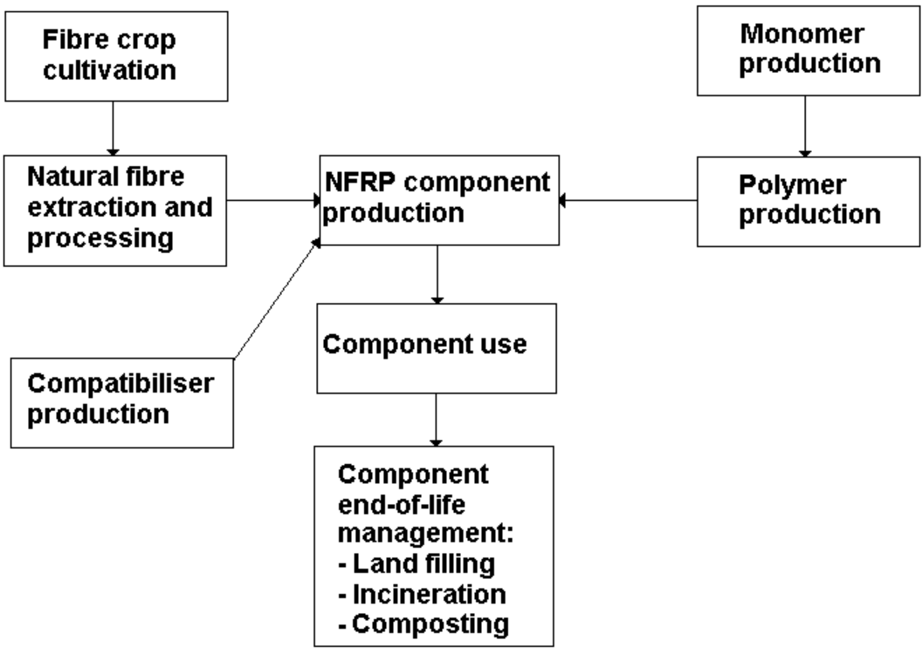

Figure 4.2 Life cycle of a natural fibre reinforced plastic (NFRP) component (elaborated from Joshi et al., 2004)

As exposed, these studies mainly concern hemp: this is not to say that coir is not suitable for hi-tech composites, experiments on coir composites for upholstery have shown good resistance to moisture, a characteristic widely sought for in industry (see also below) (CFC 2003). The other advantage of coir with respect to other fibres is that it can be seen as a by-product of a larger production, as coconut: this is not the case for most other fibres, including e.g., hemp and flax, which are produced as such, although with other primary uses than producing composite materials. In addition, there are coir products, which have strong possibilities to be successful, because effective, and can be produced locally, because they require only basic weaving technology, such as geo-textiles. As Rama Sarma (2002) reports, coir in form of strips, sheets, grids or loops can be used to consolidate clay-based soil by simply mixing it, obtaining good extensibility and increased strength and stiffness, avoiding therefore the use of bitumen for the same purpose, as from the common practice (John 1987). In spite of this, coir geo-textiles are not enjoying particular success: in contrast, they are barely surviving on the global market and have a scarce impact on local economy, since the limited profits are mainly taken by the distributors (CFC 2004). Nair (2002) suggests that the recent scarce appeal for coir, even in Sri Lanka, might include a number of coir products, including not only geo-textiles, but also wood substitutes, packaging material, garden articles, automobile accessories, which have not been popularised for commercial exploitation.

Marketing balance

To try to match the producer expectations with the buyers requirements, alternative and more appealing coir products would be needed, taking into account, as much as possible, industry requirements: this would allow the actors on the left side of the model (local coir producers) to meet the needs of the actors on the right (potential buyers of coir products). This can happen, as suggested in the model, provided that a clear strategy is in place, involving market and political considerations.

An extensive search was done through plant fibre experts and researchers, to possibly discover if marketing research had been done on new products and possible customer requirements from plant fibres. From a study carried out from the University of Plymouth on biodegradable materials use, some data have been extracted, showing the possibilities and trends in an expansion of this market. Moreover, from coir literature indications have been obtained of a possible interest for coir in the different sectors investigated in the survey (in particular Rout *et al.,* 2001, Rowell 2002, CFC 2003). The results obtained are shown in Table 4.1.

As a whole, the interest is quite high and in some cases, trials of biodegradable alternatives have been performed, however usually from crops available locally in the UK, such as potatoes. Cost can be an issue, but is compensated with the "better image" acquired from being environmentally friendly, which was associated, significantly in a couple of cases, with the concept of Fair Trade.

Table 4.1 Results of the survey on biodegradable products and application to coir

Core product	Interest for Biodegradable alternative	Characteristics looked for	Cost / volume required to be competitive	Coir use possibility
Horticultural pots/trays	Yes, trials carried out	Flexibility, moulding, water proof, frost resistant, appearance like terracotta or black plastic, surface quality	Around 5 million a year	Possible, especially if injection moulding can be used
Fast food boxes/ cups	Distribution not able to influence manufacturing (centralised: all in Finland). Trials on cups, but insufficient performance	No specified characteristics: decision on product performance taken by Headquarters on the product	No answer	Absence of pathogens required and resistance to moisture: recently proved possible. Possibly slightly too heavy
Fast food boxes/cups & plates	Tried corn-based material	Performance (able to resist fast food machinery)	3.5 pence per typical Six inch burger box	As above: there should be no problem for the resistance

Coasters and mats	Board already 85% recycled, and very price sensitive, there is little margin on disposables	Flatness essential	30 pence per sheet, which makes about 120 mats	Thickness control can be obtained with appropriate technique (e.g., compression moulding)
Fresh produce trays	Actively trialing biodegradable packaging, especially potato starch punnets	Main issue is the price, which may cause 250-300% increase in cost	Example: 1000 250g. cherry tomato punnets cost £20	Difficult, unless simple geometry for the punnet is acceptable
Fresh produce trays	Actively looking for biodegradable products	Appearance, to suit the product and be acceptable for food	Boards: Non recyclable £800/tonne, starch-based £900/tonne, maize-based £1400/tonne	As above
Stationary and cosmetic packaging	Keen on anything Fair Trade. Interested in banana based paper	Appearance and texture, functionality (especially in plastic bottles)	No answer	Possible for packaging, if thickness control and appearance is improved
Stationary and cosmetic packaging	Keen on anything Fair Trade, and/or recyclable. No trials, added chemicals to polymers to improve biodegradability	Very dependant on mechanised production and packaging requirements	Cost should be at worst slightly higher than using polypropylene	As above

Stationary and cosmetic packaging	Keen on anything Fair Trade, and/or recyclable	Long shelf life required (14 months), hence need to be moisture-free	Boxes prices: 5.8 pence small 8.6 p. medium 10 p. large	If the above are solved, moisture should not be an issue

Core of the model: national and international co-operation

The central part of the model concerns the aspects, which are crucial for the possible success of coir as a trigger for development in Sri Lanka, as long as the issues outlined in the peripheral parts are addressed. These are: the collaboration between neighbouring countries, such as for example in the case of Sri Lanka and India, both coir producers, and the importance of international agreements on products and marketing. Other actors are actively involved in the aspect of making collaboration possible and improving marketing of coir products, as Food and Agriculture Organisation (FAO) and World Trade Organisation (WTO). However, it is also important to consider that other developing countries are producers of plant fibres in competition with coir. The following data would clarify if the competition has so far a positive or a detrimental aspect on coir market, and of the whole of plant fibre market. Incidentally, one of the roles of FAO is also the promotion of marketing collaboration between Third World countries. It is interesting in this respect to see in which measure the strategies envisaged to boost this collaboration work effectively.

Sri Lanka, albeit traditionally the largest coir producer in the world, appears increasingly into difficulty, because of the concurrence of Indian coir. India and Sri Lanka together contribute 90% of the global coir production (Nair 2002). However, while global coir production has doubled since 1980, the amount of fibre traded globally has dropped by half. Growth is due primarily to the aggressive expansion of the Indian coir industry, which consumes much coir domestically and exports predominantly added-value products (Coir Cluster 2001). Comparison of the value of coir products exported from India and Sri Lanka also shows that the lower-value commodities fibre and coir pith account for half of Sri Lanka's coir exports, while more than 95% of India's export revenues are from added-value products, including yarns. Correspondingly, the average value of coir materials in exports from India is $1,000/tonne, compared to $400/tonne for Sri Lanka, so that in practice the export value of Sri Lankan coir fibre in real terms has dropped by two thirds between 1978 and 2001 (data from FAO, 2001).

It is also worthy considering that the market share is clearly defined, as giving to India, for the presence of a larger market and more R&D investment, higher added-value products than those exported by Sri Lanka. Coir Cluster suggests also that export of coir-based geo-textiles for erosion control may be able to change this situation, because of the very large request for them, which are likely to replace synthetic fabrics in the next decade. The same source also denounces, nevertheless, that Sri Lanka has lost an important opportunity on coir pith, largely required in horticulture since the early 90s. In that case, inconsistent quality and resulting customer concerns have caused a dramatic decrease in pith exports since 1999, yet they are expected to rebound in the long term (Coir Cluster 2001). Table 4.2 shows the contribution of Sri Lanka industry sectors to total exports in 2001 and industry projections for the year 2007.

Table 4.2 Sri Lanka exports of coir and coir products in 2001 and projected in 2007
(Sources: CDA, Monthly Bulletin, Dec. 2001, 2007: projections by Coir Cluster)

	Value (U$ mill) (2001)	% by sector (2001)	Value (U$ mill) (2007)	% by sector (2007)
Primary fibre products (mattress and bristle fibre)	6.3	12	6.3	8
Coir pith/Husk chips	16.1	31	16.1	20
Semi-processed materials (twisted fibre, yarn and twine)	9.9	19	10.0	13
Value added products Brooms and brushes	8.6	16	17	21
Floor coverings (mats/rugs/matting)	5.4	10	10.6	13
Rubberised coir (pads/mattresses/horticultural products)	2.6	5	5.2	7
Geo-textiles/Erosion control	3.7	7	7.5	10
New Products	-	-	6.3	8
Total Exports	**52.9**	**100%**	**79.0**	**100%**

The International Convention on Coir (Colombo 2002), aimed at promoting and facilitating the collaboration between producing countries, highlighted the possibilities for development of coir industry, by pointing out that only an estimated 10% of the husks from global coconut production are used worldwide for fibre extraction, producing about 480,000 tons of coir annually. Around 100,000 tons of this enters world trade, the balance being consumed locally in coir producing countries. While fibre demand in importing countries has declined due to inconsistency in quality and delivery, the global coir trade decreased in the last two decades from 160,000 tons to 123,000 tons (Moir 2002).

As mentioned above, consistent quality and transportation costs are critical for the success of coir production and export as a factor for development. However, also diversification of products is important, in the sense that different plant fibres are able to offer alternative properties required by the buyers, so that market competition can have a positive effect, and not result in a destructive concurrence between fibres and producing countries. In the field of geo-textiles, the report from CFC, comparing jute, sisal and coir geo-textiles, suggests exactly this strategy. Limiting for example the attention to the physical properties of geo-textiles, coir gives the highest level of bio-degradation, whilst sisal, especially in the varieties recently developed in China, is more resistant to cold, and jute absorbs considerable amounts of water, up to five times its weight (CFC 2004). This can be applied to all properties, including e.g., mechanical performance, exterior aspect (colour, coarseness) and fibre length: in general, a wide range of characteristics is available from plant fibres. This can be exploited in different ways: either trying to find a close match between the fibre, its extraction process and the function required, or producing hybrid materials, including different fibres. The real question at this point is how this can be beneficial for developing countries.

4.4 Results of the analysis: the findings

In the research questions, formulated at the beginning of this investigation, a clear emphasis was put on the so-called *natural fibre composites.* This was seen initially as the most promising way of using plant fibres to produce a biodegradable material and in addition possibly help development in producer countries, which are mostly in the Third World. This emphasis, looking at the results, needs to be corrected: some factors, as the transportation costs and the low R&D investment, the unsatisfactory quality of Third World fibres so far, make other fibres, which are cropped also in Europe, such as hemp and flax, in a better position for purposes such as use in automotive components.

As a whole, however, the substitution of glass fibres with plant fibres presents a considerable environmental interest, as from the Life Cycle Analysis data exposed, even with the limitations owed to the possible need for chemicals in the process, and to the transportation costs, which may be higher than for glass fibres.

In this context, the possibility to avoid "cash crops" considerations in the use of plant fibres exist, in the manufacture of specific high-volume products, tailored on the fibre cropped in the country to be produced locally, so to contain transportation costs. From the survey shown in Table 4.1, interest for a variety of new uses for biodegradable materials generally exists, when difficulties do not arise due to the globalisation of the market (see several answers in the survey, where Headquarters or similar centralised structures are mentioned as ultimately deciding on the product). In this case, the role of the international community can be critical, imposing, as it has been the case in the case of automobiles, the recourse to biodegradable materials in other field. The sector of packaging (e.g., for fast food) appears to be critical in this respect: here, more stringent regulations are required, which may have the added advantage of helping development through export of plant fibres. In the particular case of coir, this fibre appears in a particularly good position, because of its physical and mechanical characteristics, although the absence of pathogens in the extracted fibre needs to be ensured. A good example of products to be obtained locally from coir is that of geo-textiles, because they are likely to be used more largely in the future for erosion protection with considerable environmental advantage, due to their high biodegradability. In addition, geo-textiles involve limited technology and use of basic machinery for weaving, spinning, etc. However, concerns may arise is that local people may not be prepared to a philosophy of quality control, as required by the modern construction industry, and that political stability is necessary to have consistent supply and price. On the latter, international agreements will be necessary in the long run, because of the potential high added- value for geo-textiles, when installed e.g., on eroded slopes close to expensive state-of-the-art motorways.

4.5 Summary

The results obtained were disposed according to the conceptual model, presented in Chapter 3: in this way, first some LCA data were included, to prove the environmental significance of replacing glass fibres with plant fibres as plastic reinforcements. After this, a survey on industrial interest of biodegradable materials, including considerations on coir in this context is included and, on the other side, the offer from coir producers is presented. Use of coir for geo-textiles is revealed as being more promising than for plastic reinforcement, especially considering the difficulties in quality control and the diffuse criticism about insufficient technology transfer in Sri Lanka. In addition, a number of new products from coir could be proposed in alternative sectors, such as packaging.

5. Conclusions

5.1 Introduction

This study examined the possibility for an increased application of plant fibres in industrial context, in particular to replace glass fibres as a reinforcement of composite materials, to result both in a benefit for the environment and in an advantage for fibre producers, which are mainly developing countries. In particular, the case of Sri Lanka, the largest world producer of coir (coconut fibre) was considered in a longitudinal case study, aimed at looking at the perspective of this fibre and more in general of plant fibres in the global market of the next decade.

The methodology involved the creation of a conceptual model. This aimed to clarify the role of the different actors in the process of making coir a fibre suitable for a variety of applications in the next future, excluding, as far as possible, its exploitation as a "cash crop" and creating possibilities for development in Sri Lanka, as well as an environmental benefit worldwide.

The results show that there is scope for some optimism in this respect, provided that diversification of coir products and improvement of quality is obtained, with the support of international organisations and possibly inter-state collaboration.

In this chapter, conclusions are presented that try to qualify these possibilities. Section 5.2 is aimed at evaluating the likeliness that coir can be used with the best results both for environment and development, whilst section 5.3 is intended at highlighting the difficulties that hindered this process in the past, and the future perspective in this respect. Section 5.4 aims to look at the larger picture of what coir, and natural fibres, can represent in the whole issue of Third World development, whilst suggestions for future work are presented in section 5.5.

5.2 Conclusions about the research problem

Coir, as most other natural fibres, offers extensive possibilities for exploitation, in that it is suitable for a very large number of uses. Moreover, coir is a by-product of coconut palms, so that it is a part of a larger process, which in principle can offer a variety of products and serve as a real boost for economy in the world's larger producer country, Sri Lanka.

In attempting to relate these facts with the first research question posed i.e., whether the production of coir-based products is as environmentally friendly as the coir fibre intrinsically is, an important distinction needs to be made. This concerns the different technological content that coir fibre applications present, which is high in the case e.g., of automotive components, and low in the case of other products, including e.g., coir pith for plants. This different technological content is reflected also in the complexity of the manufacturing process, which also has an effect on the environmental impact. For example, whilst it is difficult to obtain chemical-free composite materials reinforced with natural fibres for automotive applications, where a very high resistance to impact damage is required, this appears in contrast possible in wood replacement boards for upholstery, a specific application in which coir was used (CFC 2003). As a consequence, most studies of environmental sustainability in the form e.g., of Life Cycle Analysis on natural fibre composites, some of which were presented in section 4.3, concern automotive components, and, albeit showing some promising trends, are mainly focused on hemp. The reason for this is that in practice, manufacturers of automotive components are usually using hemp and possibly flax of European origin, also because of incentives from the European Union (see e.g., Specht *et al.,* 2004 and Spengler, 2003). Jute in door panels has been introduced since 1996 in the German car industry, but the future trend appear to be towards the use of fibres from European plants, also due to the lower transportation costs (Wotzel *et al.,* 1999). Indian car manufacturers also use jute in some internal panels, but this is rather due to their jute production that largely exceeds their needs, than to environmental or development considerations (Nangia *et al.,* 2000). However, LCA studies available so far are not always adaptable to possible high volume applications of plant fibres, such as e.g., for food packaging purposes. On the other side, market surveys such the one presented in section 4.3, suggest there is scope for some action in fields such as the above, where coir can play its role, provided that packaging suppliers are available (or "convinced" by other economic measures) to use local materials locally. Coir-based packaging would also need to be pathogens-free: this would require either covering with some biodegradable (starch based) film, or disinfecting the material prior to use (Korde 2004).

It is important to observe, however, that the lower technological content of applications selected does by no way mean that it is easy to have success in their production and marketing. Inconsistency in quality and supply of coir pith for horticultural purposes, as described in section 4.3, turned customers away from this product, with negative consequences for Sri Lanka economy.

In general, there is need, as suggested in a number of papers (e.g., Nair (2002), Moir (2002) and Coir Cluster (2001)) for some re-thinking of the coir production process. This would involve tailoring the properties of the fibres, as much as possible, on alternative applications, exceeding both the traditional (mats, carpets, etc.) and the highly technological ones (plastic replacement for automotive components). Geo-textiles for erosion control are a good example of what could be done: on one side there is the need for plastic replacement in this field, on the other side most geo-textiles can be obtained with processes which are fairly easy, well-known and practised locally (weaving, knitting, knotting, and needle-punching) (CFC 2004).

Possible "added value" of coir fibre application can bring back the exploitation of this raw material with a "cash cropping" philosophy, which is the core of the second research question posed. However, one solution can be, rather than the integration of fibres in high-value materials, such as automotive components, their use for low-value materials, presenting a very large interest and function all over the world, including the developing countries. For example, a net of knotted coir has a value that barely exceeds that of the pure fibres used, whilst the same net used as a geo-textile in construction engineering considerably enhances the value of the built works. On motorway slopes or embankments, e.g., it provides an improved resistance to erosion, and does not need to be replaced when the plants start to grow, because it acts as compost for them, which is not the case with synthetic nets (John 1987). International agreements may help in this regard, as the action of organisations, such as FAO and WTO. In practice, Nair suggests some indications for the role of a possible international forum on coir, to be created after the conference on coir in Colombo (2002). This should promote product growth and diversification through research, development of market and human resources, quality improvement, transfer of technology and exchange of market intelligence (Nair 2002). However, the relation between Sri Lanka and its larger neighbour, India, will be contributing substantially to the success to this initiative, since, as mentioned above, these two countries represent 90% of coir production in the world.

From these considerations, it is fairly straightforward to come to the third research question: how these processes of product growth and diversification can resist the increasing globalisation of worldwide trade. The answer appears to be possibly coming from the synergy of three actions: international co-operation, *in-situ* development of new applications and control at governmental and inter-governmental level over unnecessarily added costs (e.g., monopoly over transportation). All of these aspects need to be possibly inserted in a frame of real resistance to cash cropping, as experimented in some cases against coffee, especially in Africa (see e.g., Turner *et al.,* 2000, O' Laughlin, 2002). An interesting suggestion is also that variability in prices of coir can affect its perspectives as a cash crop, which means that even stronger international trade collaboration will be needed in hard times to "push" the products for new applications, such as geo-textiles (Kelly *et al.,* 1995).

5.3 Conclusions about the practical and theoretical problems

From the investigation, coir has revealed itself as a very promising fibre, which is very far from fulfilling its possibilities. A variety of uses appears to have just started to be exploited. In spite of this, the whole plant fibres market appears to be declining. This trend is unlikely to be due to a scarce need for the application of biodegradable materials, as it cannot reasonably be attributed to an insufficient interest from possible users, as shown in Chapter 4. It is true, nonetheless, that globalisation is able to affect the adoption of innovative uses of biodegradable materials, since the tendency is to use worldwide the same material, or the same combination of materials, to produce the same object, or to carry out the same function. In addition, the negative effect of a low level of quality control, of a supply not always matching the demand (for political or organisational reasons) and of oscillations of transportation costs needs also to be recognised.

The above factors need of course to be addressed, possibly with the assistance of international organisations, not only by establishing fair commercial agreements, but also providing technology transfer, in order to promote development in the producer countries, meanwhile improving the global environment.

The real problem can be the absence of future projection in coir production and marketing. This means in practice that estimates on the use of coir in next few years, such as the one presented in Table 4.2, appear biased by a number of hidden assumptions. A first assumption is that coir will still be used mainly for traditional purposes (coir pith, brooms, mattresses, etc.). When "new products" are presented, as suggested by Coir Cluster (2001), these involve materials for the automotive sector and other applications with higher technological content than the present ones. A second assumption is that international collaboration represents a very hard problem, even between India and Sri Lanka, so that little technology and expertise transfer will ultimately be possible.

It is difficult at this stage to clarify whether these assumptions are realistic or not. It appears evident, nonetheless, that in this way some commercial events, which are to take place in the foreseeable future, and may benefit the coir market, are overlooked. One of these is the large expansion of demand for biodegradable geo-textiles, especially in the developed world, where synthetic geo-textiles are applied since the Sixties. A second one is the requirement for biodegradable products in sectors, such as fast-food packaging, needing *large volume* production, carried out *locally* to contain costs.

5.4 Implications

This research has shown that replacement of oil-based plastics with natural materials can present advantages for the environment: however, market globalisation imposes the use of plastics, also when local fibres are available. For this reason, it is important that locally an awareness of the full possibilities of the local materials is reached. In coir producing countries, only a small fraction of coir available as a by-product of coconut palms is actually sold. Moreover, this fibre has still, as many other natural fibres, a rather "pale" marketing image, being associated to old-fashioned and poor carpets and mats.

Another implication is that any program for Third World development based on natural fibres will hardly be succeeding, if there is no Fair Trade: the two concepts are strictly related. In other words, the price paid for the raw materials used to manufacture added-value goods (such as for example plant fibres used to manufacture geo-textiles or automotive components) is not based on the final price at which the goods are valued, for example as part of a building or of an automobile. If this is achieved, the growing interest in a more severe legislation on end-of-life scenarios may constitute an occasion for developing countries cropping fibres to be used in biodegradable materials.

A third consequence refers to the way the above development should take place: most studies and analyses have concerned high-tech applications, such as hemp fibre air conditioning systems, as shown in Chapter 4. In reality, problems in quality control and difficult technology transfer suggest that developing countries do not neglect large volume applications of biodegradable materials, which may be equally, if not more, important for their development. It is crucial that at the level of international co-operation, as well as at the level of national and local government, there is willingness to use the existing local knowledge of the fibres and of basic technology. This has more possibilities to work, especially in the immediate future, than imposing an "extraneous" process, such as the production of automotive components using coir fibres.

5.5 Further work

The possible effect of use and marketing of plant fibres on development of producer countries, such as Sri Lanka, can change considerably upon time. In particular, new products can be obtained, on which Life Cycle Analysis studies will be necessary, and a considerable effort of R&D will be required. LCA will particularly become interesting in those cases, more and more frequent, where more than a fibre is used: in this case, once again, transportation costs will need to be included important in the analysis, so more refined analysis tools, such the Econo-Environmental Return (EER), will necessarily come into the picture.

In a few years time, it is very likely that this study will need also to involve evaluating Fair Trade prices for new coir-based products, and suggesting measures to improve the convenience of manufacturing biodegradable materials, especially in developing countries.

In this respect, it will be necessary to look back at the history of collaborations between neighbouring countries, and to the effects of competition between different plant fibres. In particular, it is essential to trace back the consequences of the actions of international organisations, such as FAO or WTO, trying to evaluate if these are just promoting development or may be also capable of providing Fair Trade conditions for plant fibre suppliers.

5.6 Summary

New uses for coir and other natural fibres, including e.g., nets for erosion control (geo-textiles) and alternative uses, such as in food packaging, can result in development for producing countries and in a benefit for the global environment. For this scenario to become realistic, a number of conditions are needed, including a stringent environmental legislation, international commercial agreements and political stability in the developing countries. These requisites are able to create conditions for Fair Trade and development, preventing the effects of globalisation and allowing the most environmentally suitable materials to be used for a number of functions and industrial sectors. The game is to be played in the next few years, not only for Sri Lanka, but also for a number of developing countries, to cope with new needs from the industry, involving use of natural fibres for better sustainability and requiring a highly qualitative production, based locally. If this can be obtained in due time, remains to be seen.

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Appendix

Principal plants from which fibres are extracted for use in materials

Plant	Botanic name	Fibres extracted from…
Coir	Cocos nucifera	Fruit hair
Jute	Corchorus sp.	Stem
Flax	Linum usitatissimum	Stem
Hemp	Cannabis sativa	Stem
Bamboo	Various species	Stem
Sisal	Agave sisalana	Leaf
Abaca	Musa textiles	Leaf
Ramie	Boehmeria nivea	Stem
Esparto	Lygeum spartum Stipa tenacissima	Stem
Kenaf	Hibiscus cannabinus	Stem
Roselle	Hibiscus sabdariffa	Stem
Banana	Musa sapientum	Leaf
Date palm	Phoenix dactylifora	Leaf
Oli palm	Elaeis guineensis	Fruit hair
Sunn hemp	Crorolaria juncea	Stem
Spanish Broom	Spartium junceum	Stem
Betelnut	Araca catechu	Seed hair
Pineapple	Ananas comosus	Leaf
Piassava	Attalea funifera	Leaf
Lady's fingers	Abelmoschus esculentus	Bark
Kapok	Ceiba pentandra Ceiba occidentalis	Fruit hair